

REMARKS

Reconsideration and allowance of this application, as amended, are respectfully requested. Applicant agrees to the drawing changes recommended by the Examiner. Corrected drawings will be filed at the appropriate time in the prosecution of this application. The prior art grounds of rejection are respectfully traversed. The claims are not amended at this time.

Figure 12 of the Akiyama reference shows that N^- concentration is $2.5 \times 10^{15} \text{ cm}^{-3}$ at its lowest. Attached for the Examiner's reference in Attachment A are pages 102 and 103 of "Physics of Semiconductor Devices". Figure 29 is enlarged and reproduced below:

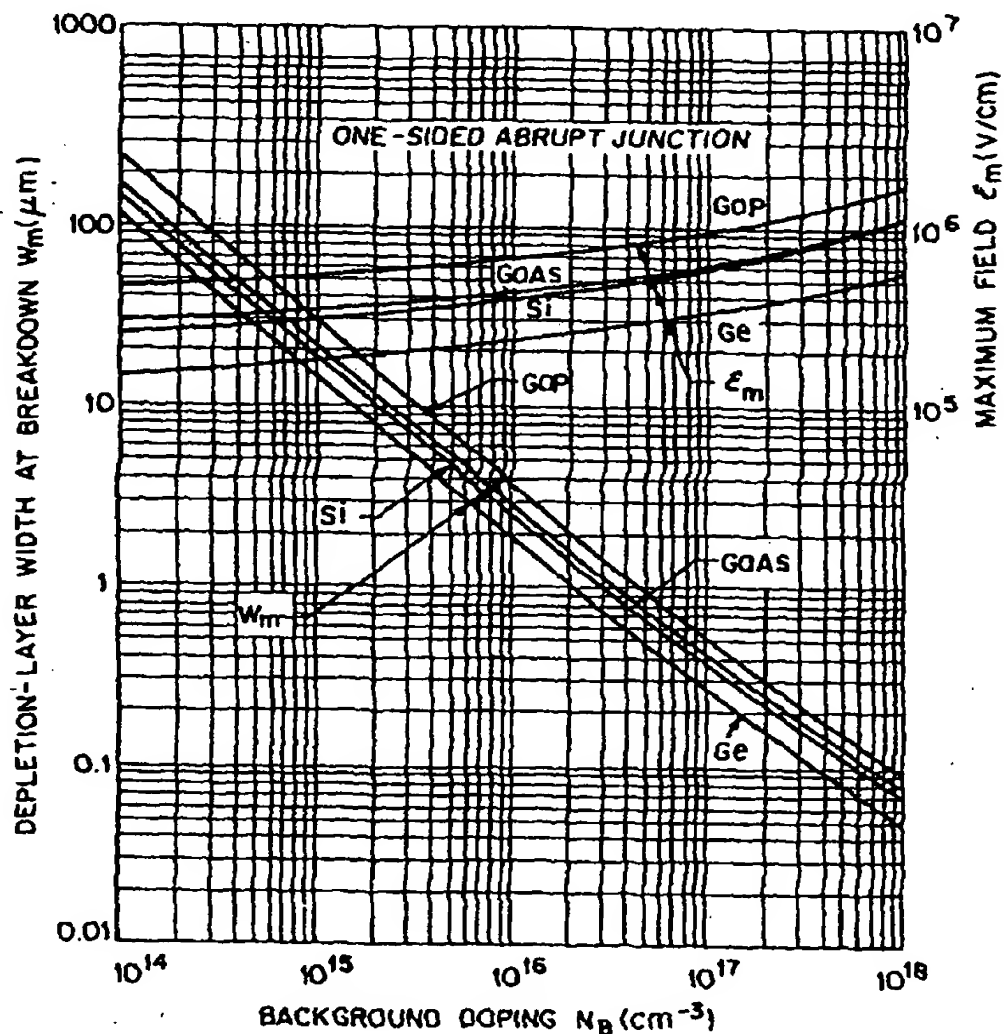
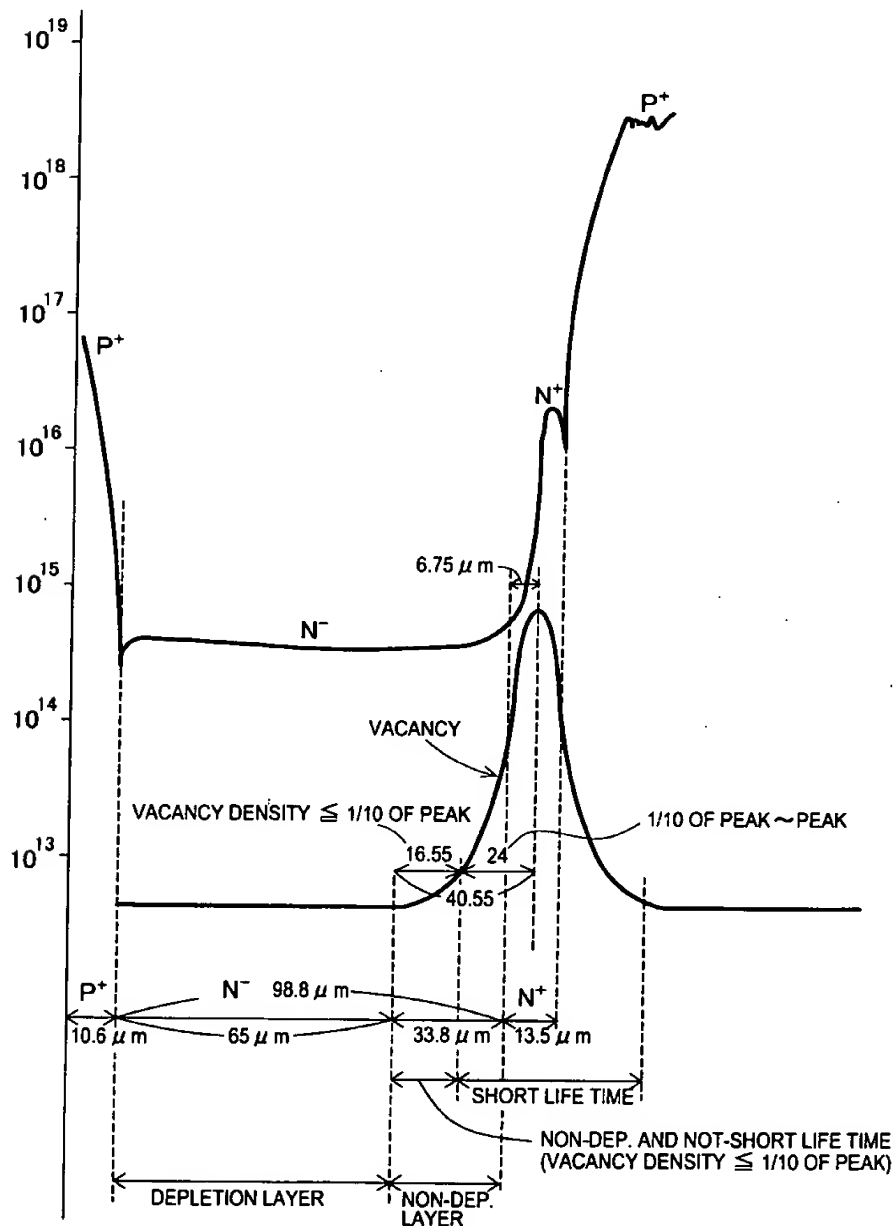


Fig. 29 Depletion-layer width and maximum field at breakdown for one-sided abrupt junctions in Ge, Si, (100)-oriented GaAs, and GaP. (After Sze and Gibbons, Ref. 35.)

Referring to Figure 29 of Attachment A, one can determine that the depletion layer of the Akiyama arrangement can extend up to only $65\text{ }\mu\text{m}$ with such a low N^- density. Accordingly, there spreads $33.8\text{ }\mu\text{m}$ of non—depletion region in the N^- region 2B. The following drawing is a composite of Figure 12 and Figure 15 of Akiyama.

COMPOSITE GRAPH OF FIG.12 AND FIG.15(AKIYAMA.)




The distance between a point where vacancy density is $1/10$ of peak and a peak point is of about $24\text{ }\mu\text{m}$. Therefore, in the Akiyama arrangement, it is apparent that there exists about $17\text{ }\mu\text{m}$ of region that is not depleted and has insufficiently short life time (i.e., vacancy

density is same as or lower than 1/10 of peak). Accordingly, the structure of Akiyama is quite different from those of our claimed inventions where the entirety of non—depletion has sufficiently short lifetime. In other words, in Akiyama, the entirety of non—depletion region does not include sufficiently short—lifetime region.

In view of the above remarks, it is respectfully urged that the claims are patentable over the Akiyama et al. reference.

Respectfully submitted,
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ATTACHMENT

Attachment A – pages 102 -103 “Physics of Semiconductor Devices”

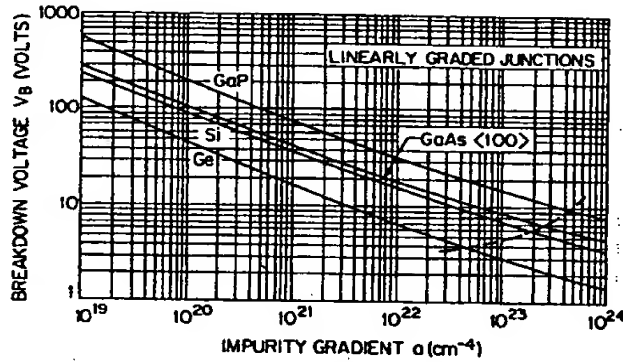


Fig. 28 Avalanche breakdown voltage versus impurity gradient for linearly graded junctions in Ge, Si, (100)-oriented GaAs, and GaP. The dashed line indicates the maximum gradient beyond which the tunneling mechanism will set in. (After Sze and Gibbons, Ref. 35.)

In GaAs, the ionization rates depend on crystal orientations (refer to Chapter 1). Figure 27 shows a comparison³⁷ of V_B in (111) and (110) orientations with respect to that in (100). Note that at around 10^{16} cm^{-3} , the breakdown voltages are essentially independent of orientations. At lower dopings, V_B in (111) becomes the largest; whereas at higher dopings, V_B in (100) is the largest.

Figure 28 shows the calculated breakdown voltage versus the impurity gradient for linearly graded junctions in these semiconductors. The dashed line indicates the upper limit of a for which the avalanche breakdown calculation is valid.

The calculated values of the maximum field \mathcal{E}_m and the depletion-layer width at breakdown for the four semiconductors above are shown³⁵ in Fig. 29 for the abrupt junctions and in Fig. 30 for the linearly graded junctions. For the Si junctions, the maximum field can be expressed as³⁸

$$\mathcal{E}_m = \frac{4 \times 10^5}{1 - \frac{1}{2} \log_{10} (N_B / 10^{16})} \quad \text{V/cm} \quad (78)$$

where N_B is in cm^{-3} .

Because of the strong dependence of the ionization rates on the field, the maximum field varies very slowly with either N_B or a . Thus as a first approximation we can assume that, for a given semiconductor, \mathcal{E}_m has a fixed value. Then from Eq. 77 we obtain $V_B \sim N_B^{-1.0}$ for abrupt junctions and $V_B \sim a^{-0.5}$ for linearly graded junctions. Figures 26 and 28 show that the foregoing patterns are generally followed. Also as expected, for a given N_B or a , the breakdown voltage increases with the energy bandgap, since the avalanche process requires band-to-band excitations.

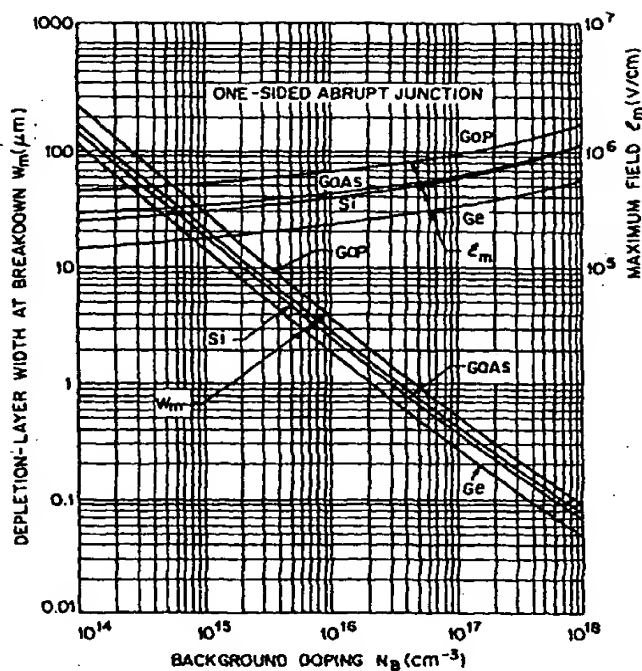


Fig. 29 Depletion-layer width and maximum field at breakdown for one-sided abrupt junctions in Ge, Si, (100)-oriented GaAs, and GaP. (After Sze and Gibbons, Ref. 35.)

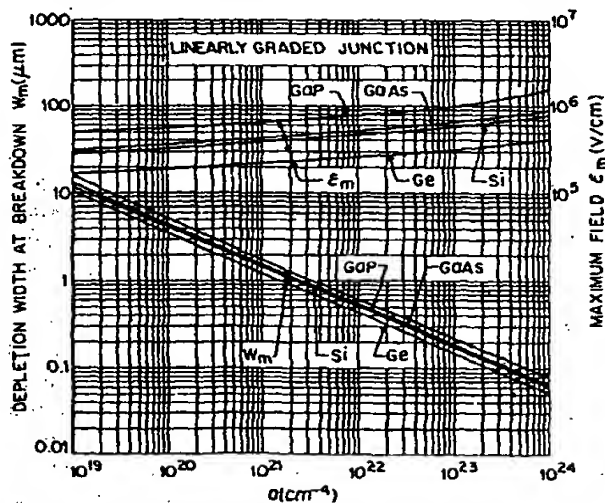


Fig. 30 Depletion-layer width and maximum field at breakdown for linearly graded junctions in Ge, Si, (100)-oriented GaAs, and GaP. (After Sze and Gibbons, Ref. 35.)